Changed micro-nutrient recommendations for Atlantic salmon (*Salmo salar*) when fed diets based on plant ingredients.

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ARRAINA,
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Background – why new recommendations for Atlantic salmon when feeding on plant based diets?

Initial lower appetite (LOWERED GROWTH)
Increase lipid stores

70 % Plant oil
80 % Plant prot.

Estimated safe max replacement to meet all nutrient requirements

100 % Fish oil
100% Fish prot.

(Torstensen et al. 2008)

REQUIREMENTS ??
How to determine nutrient requirements for production of robust farmed fish?

* Identify nutrients “at risk” in a PP and VO diet

* Identify suitable biomarkers for requirement

* Make ONE mixture of minerals, vitamins, etc.; would be able to identify interactions, and give new recommendations

* Analyse biomarkers and identify the break point / safe concentrations
Based on state-of-the-art knowledge, and
• Dose response (as classic)
• Nutrient retentions (storage)
• Early biomarkers (specific for each nutrient) &
• Combined with genetic markers
Experimental conditions and design (fresh and seawater experiments)

- Temperature: 12.4 °C (±0.7) freshwater (ambient in seawater)
- Feeding: continuous
- Collection of uneaten feed: daily (except weekends; freshwater only)

Basic diet
0% NP  25% NP  50% NP  100% NP  150% NP  200% NP  400% NP

NP = Nutrient package
Water-soluble vitamins – vitamin C and the B-vitamins (pyridoxine, biotin, cobalamin, folate, pantothenic acid, riboflavin, thiamin, nicacin).

Lipid soluble vitamins: A, D, E, K

Minerals: Se, I, Cu, Co, Mn, Fe, Zn
Amino acids: Met, His, Lys, Taurine,
Lipids: Chol added, (no variation in n-3 n-6 FA profile).
Growth results confirm AquaMax findings – some nutrients lacking at 100% NP in plant based diets

WHICH?????
Lipid retention changed

Same pattern as for growth; 4 lowest vs 3 highest diet groups

HSI: \( R^2 = 0.46, \ p = 0.03 \), VSI: \( R^2 = 0.48, \ p = 0.02 \)
Growth performance in seawater confirmed results in freshwater

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SGR

Liver index

Viscera-somatic index

R²=0.48, p=0.003

R²=0.46, p=0.03

R²=0.48, p=0.02
mRNA levels of genes related to growth (confirmed as growth markers):

**IGF1**

**GHR2**
mRNA levels of genes related to lipid metabolism

Capacity of β-oxidation and peroxisomal oxidation increased by NP
B-vitamins – fresh water

Pantothenic acid in gills

$R^2 = 0.72$, $p < 0.0001$
Classic deficiency of pantothenic acid: CLUBBED GILLS remains to be confirmed in ARRAINA
B-vitamins – fresh water

Early biomarker: blood remains to be evaluated; but tissue saturation at (NRC 2011)

$B_{12}$ deficiency megaloblastic anemia
B-vitamins – fresh water

Pyridoxine essential for protein turnover

- No tissue saturation
- Early biomarker ASAT (transaminase); increased at the 150% level
- Genetic biomarker: (IGF-1 «saturated» at the 150% level
B vitamins (seawater at GIFAS)

Confirm freshwater results
B-vitamins – fresh water

Thiamin essential for enzymes involved in carbohydrate metabolism; Tissue saturation obtained at NRC recommended level for salmonids.
B-vitamins freshwater

Biotin essential for carbohydrate, lipid and protein turnover; no changes in tissue levels due to diet.
Niacin; essential for NADH function transferring e- and H+ in red-ox reactions
No tissue saturation; genetic biomarkers (genetic red-ox enzymes)
Vitamin E

No saturation reached – any connection to liver function???
Red-ox system?
Genetic markers for red-ox

CAT

CuZn SOD

GPX1

MnSOD
Conclusions

Multivariate approach can be used if biomarkers and specific symptoms can be connected to single nutrients, need more than growth and tissue saturation, biomarkers important.

Recommendations for plant based diets to Atlantic salmon; the multivariate approach revealed that NRC must be added surplus (50% more) of the following nutrients:

- Pahtothenic acid, pyridoxine, niacin.
- More results needed for the lipid soluble vitamins
Thank you for your attention

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